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Abstract

Many scenario studies conducted by several countries consider the progressive deployment of low void effect Sodium-cooled Fast Reactor (SFR) [1]. Different options are investigated regarding the deployment time of this kind of Generation IV reactor, depending on the global nuclear energy development and the national energy mix strategies. In France, the SFR core design often used in this type of scenario is based on the 600 MWe ASTRID concept developed by the CEA and its industrial partners [2]. To reach a negative void coefficient, the core is divided in two radial parts: an inner and an outer core, which alternate different fertile and fissile zones.

One challenge to simulate fuel cycle with fuel reprocessing is to consider the evolution of the materials to be recycled over time. Indeed, spent fuel compositions vary at each reprocessing as it depends of each fuel history (in which reactor it has been irradiated, burn-up achieved, cooling time…). Hence, to build a fresh fuel adapted to one reactor specificities, the CLASS (Core Library for Advanced Scenario Simulation) software [3], a dynamic fuel cycle simulation code developed by CNRS in collaboration with IRSN, uses dedicated fuel loading models.

In the case of this SFR, the aim is to keep the fuel heterogeneity of the core. To do that, the development of a new dedicated fresh fuel loading model taking into account the different fuel zones of the reactor was needed. This model is based on the reactor's neutron characteristics and it is usable for a wide variability of spent fuels to be recycled. In this way, for a given isotopic composition, the Pu contents of both the inner and the outer core are iteratively adjusted to reach a target power distribution in the core and a target multiplication factor (k_{eff}) at the beginning of cycle.

An analysis of this SFR behavior during irradiation shows a relation between the power distribution and the ratio of Pu contents, between the inner and outer core. This relation is used by the model to calculate the initial Pu contents for a given isotopic composition assuring the target power distribution. Then, to determine the k_{eff} associated to that specific fresh fuel composition, the model uses Artificial Neural Network (ANN) trained on a corresponding databank. This databank is composed of 1000 full core depletion Monte Carlo simulations generated with the VESTA code [4], in which MCNP is used as the transport solver. Each calculation differs from the other by the initial fresh fuel sampled in the parameter space of compositions covering many potential SFR fuel management strategies.

This new model completes the implementation of a previous multi-zone fuel irradiation model developed for this SFR [5]. Thanks to these two multi-zone models, the simulation of scenarios integrating multi-zone SFR with the code CLASS shows that the plutonium breeder, break-even or burner SFR property is highly dependent on its fresh fuel composition.

References

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